LEGIBILITY NOTICE

A major purpose of the Technical Information Center is to provide the broadest dissemination possible of information contained in DOE's Research and Development Reports to business, industry, the academic community, and federal, state and local governments.

Although a small portion of this report is not reproducible, it is being made available to expedite the availability of information on the research discussed herein.

1

LA-UR -89-1572

Received by OS[illegible]

JUN 07 1989

LA-UR--89-1572

DE89 013207

TITLE: TUNING MAGNET POWER SUPPLY

AUTHOR(S): B. M. Han and G. G. Karady
Arizona State University

H. A. Thiessen, MP-14

SUBMITTED TO: 1989 Particle Accelerator Conference
Chicago, IL
March 20-23, 1989

Los Alamos Los Alamos National Laboratory
Los Alamos, New Mexico 87545

MASTER

TUNING MAGNET POWER SUPPLY

B.M. Han, G.G. Karady
Arizona State University
Tempe, AZ

H.A. Thiessen
Los Alamos National Lab.
Los Alamos, N.M.

ABSTRACT

The particles in a Rapid Cycling Accelerator are accelerated by RF cavities, which are tuned by DC biased ferrite cores. The tuning is achieved by the regulation of bias current, which is produced by a power supply. The tuning magnet power supply utilizes a bridge circuit, supplied by a three phase rectifier. During the rise of the current, when the particles are accelerated, the current is controlled with precision by the bridge which operates as a power amplifier. During the fall of the current, the bridge operates in a switching mode and recovers the energy stored in the ferrites. The recovered energy is stored in a capacitor bank. The bridge circuit is built with 150 power transistors. The drive, protection and control circuit were designed and built from commercial component. The system will be used for a RF cavity experiment in Los Alamos and will serve as a prototype tuning power supply for future accelerators.

INTRODUCTION.

The beam in a rapid cycling accelerator is accelerated by RF tuned cavities, which are directly coupled to the anode of a powerful klystron tube. The cavity is continuously tuned to the resonant frequency of the system. The tuning range is narrow, but efficient energy transfer requires high precision. Accurate tuning is achieved by DC current biased ferrite cores, located at the end of the cavity. The bias windings are placed between the ferrite cores and supplied by a controllable power supply. The power supply is placed in a feed back loop, which controls the bias current and tunes the cavity. The bias current varies between 600 to 1500 A.

This paper describes the accurately controllable power supply which was developed for tuning the RF cavities.

REQUIREMENTS.

The tuning magnet power supply drives a current impulse through the bias winding. The required current and the corresponding voltage are shown in Figure 1.

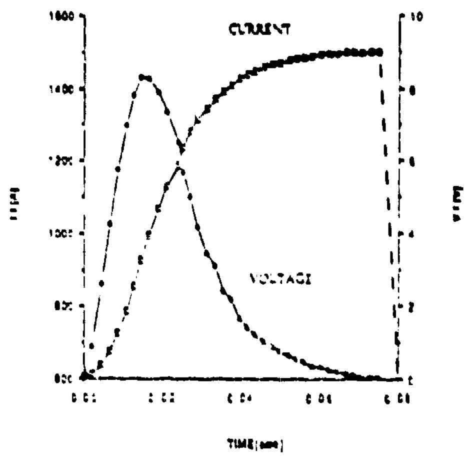


Figure 1. Required current and voltage.

The rising part of the current wave has to be controlled very accurately. It has to follow the required waveform with better than .1% accuracy.

The descending part of the wave does not affect the accelerator operation. The current has to be controlled in such a way that the induced voltage is minimized.

The bias winding has low resistance and represents a mostly inductive load. This inductance stores a considerable amount of energy when the current is maximum. This energy has to be dissipated or recovered during the current descent. The latter is the desirable and selected solution. Also, the inductive load makes accurate current control difficult, because change of current requires high voltage. A further complication is that the ferrite saturates during the current rise. In addition, the system requires about 600 A DC bias current, which represents a constant load.

POWER SUPPLY CONCEPT AND OPERATION.

During the development of the tuning magnet power supply circuitry, several different concepts were investigated and the most promising ones were tested. The result of these studies is the circuit shown in Figure 2.

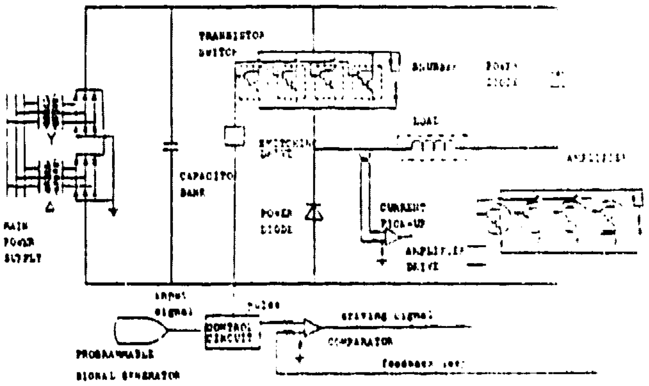
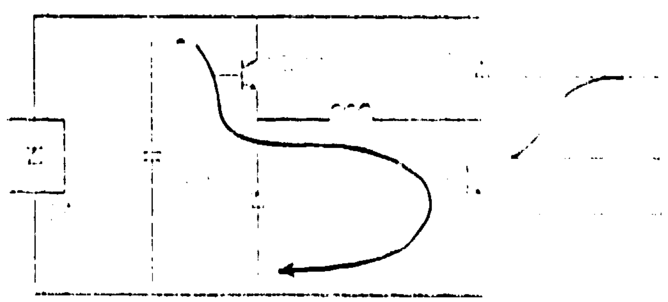


Figure 2. Tuning Magnet Power Supply configuration.

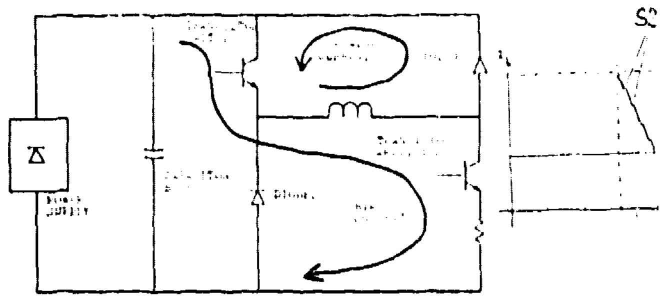
The system operation is divided into three states, which are shown in Figure 3.



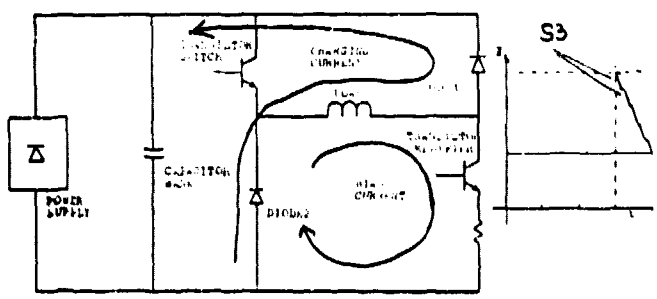
State 1. The current increases in amplifier operation mode.

Figure 3a. Operation modes.

In State 1 the transistor switch is on and the increasing current is controlled by the large transistor amplifier. This mode permits accurate and continuous current control. A special aspect of the circuit is that the amplifier is supplied by a decreasing voltage of the capacitor bank, which stores the magnetic energy of the ferrites. When the current reaches its maximum value, the circuit is changed to a switching mode. In this mode, the amplifier is turned off and the



State 2. Switching operatio.ı. Current is constant.



State 3. The current decreases in switching mode.

Figure 3. Operation modes.

transistor switch is turned on and off, using the pulse modulation techniques This operation has two states:

In State 2 the transistor switch is on and the inductance current is freewheeling through the diode. Because of the low circuit losses, the current decreases slowly.

In State 3 the transistor switch is off and the inductive current charges the capacitor bank, this recovers the energy. The capacitor bank voltage decreases the current rapidly.

By the selection of the on and off times, the current descent can be regulated fairly well. The energy recovered from the ferrite increases the voltage of the capacitor bank by 10-15 %.

Figure 4. Transistor Switch circuit.

When the current is decreased to the bias current level the system is switched to State 1 and the amplifier maintains the ferrite current at the bias value. At the beginning of the next cycle the control signal regulates the amplifier, which increases the ferrite current.

COMPONENT DESCRIPTION.

The system is supplied by a 30V, 1500A three phase rectifier, which provides filtered DC voltage. The rectifier is protected by a fast acting circuit breaker, which has overcurrent protection and can be operated remotely.

The capacitor bank is rated to 60V and 6.5 Farad.

The transistor switch consists of four Darlingtons connected in parallel, each of them, is rated 500V and 400A. The Darlingtons are equipped with a snubber circuit and controlled by an optically insulated switching drive circuit. The transistor switch is water cooled and its circuit is shown in Figure 4.

The diodes are water cooled high power units rated at 1000A and 500V.

The amplifier is built with 150 power transistors connected in parallel. The transistors are divided into 15 modules, each protected by a fuse. Equal current sharing is assured by a 0.03 ohm resistor connected in series with each power transistor. The bases of the transistors are supplied through a protection diode by an amplifier drive circuit, consisting of operational amplifiers and high power transistors.

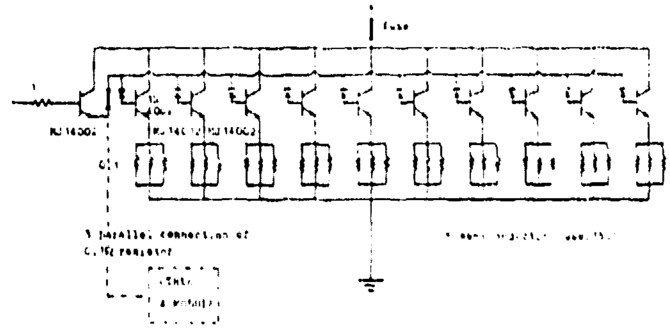


Figure 5. Amplifier Module.

CONTROL CONCEPT

The tuning magnet power supply operates in a feed back circuit and receives an analogue control signal. The ferrite bias current has to follow the increasing part of the signal with high accuracy, however, the current has to decrease to the bias current value before the next cycle starts. Linear current descent is selected, but any other wave shape can be obtained. The control concept is shown in Figure 6.

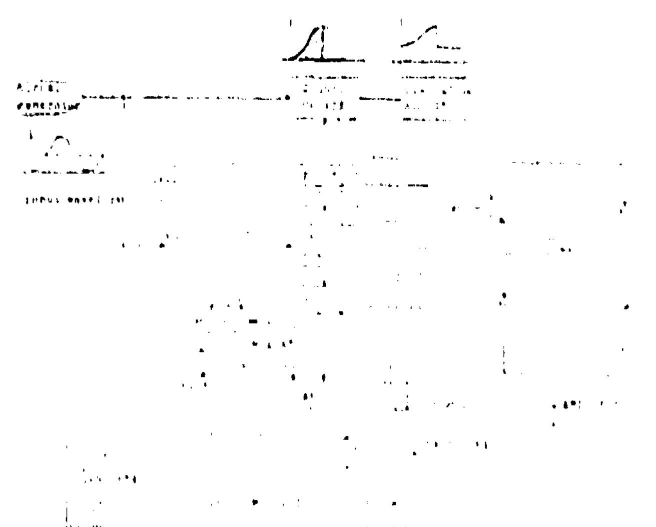


Figure 6. Control Concept

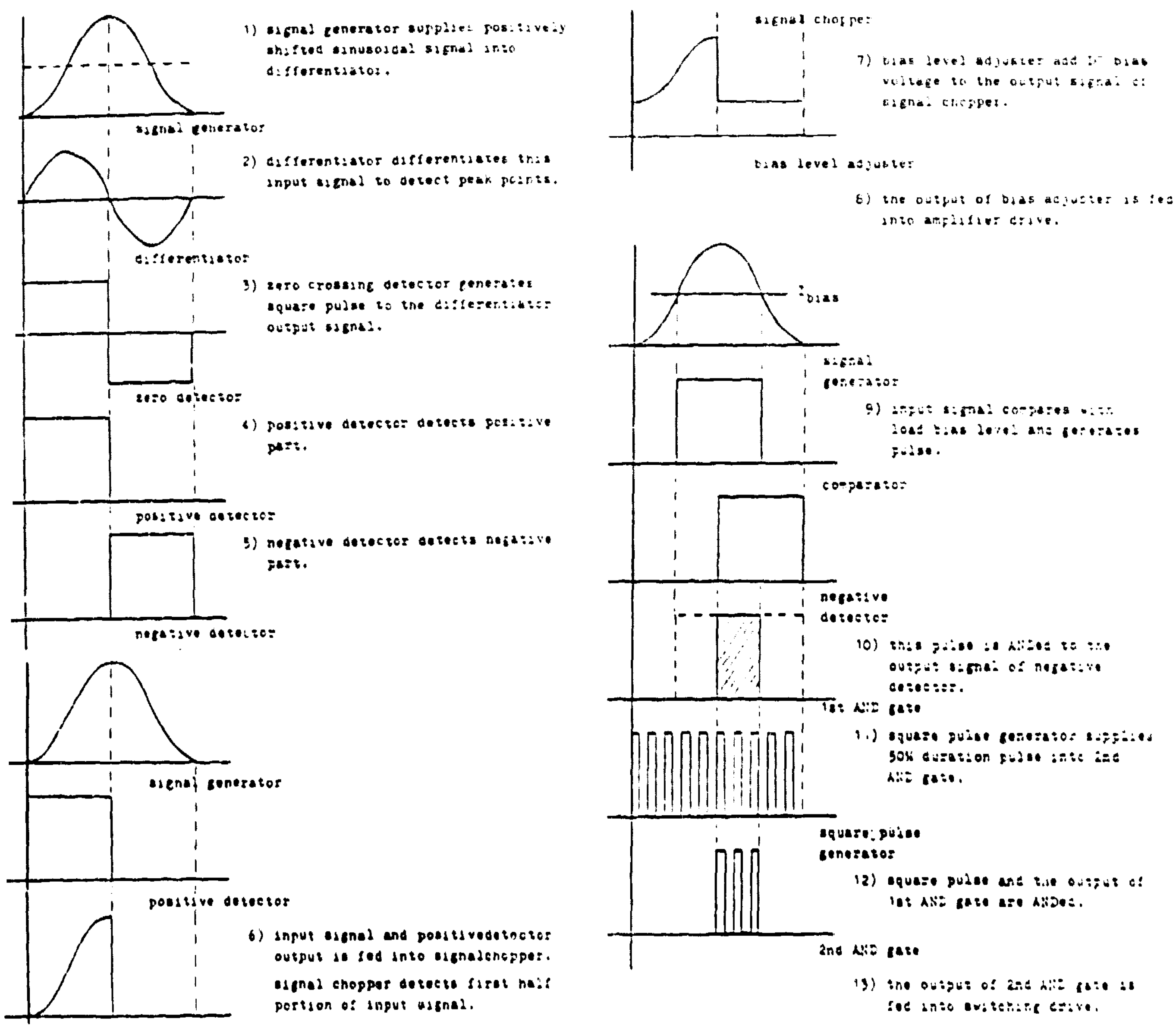


Figure 7. Control circuit operation

The amplifier drive circuit has a feedback loop that increases the circuit accuracy. The operation of the control circuit is described in Figure 7. The circuit was tested with a biased sine wave.
The main components of the system are protected by high power fuses. In addition, a separate protection circuit is built in the control cabinet. This circuit monitors the voltages and the currents of the critical components and switches off the main circuit breaker in case of an overload or overvoltage. The condition of the fuses is also monitored. The operation of the fuses is indicated on the control panel. If more than three fuses are blown, the protection circuit shuts down the main supply.

CONSTRUCTION

The proper operation of the system was verified at first by computer model, which simulated the operation of the system. This computer model was used as a design tool. The maximum and average currents and voltages of the components were calculated. This lead to the accurate design of the components.

Upon the completion of the system design, a scaled down model circuit was built and tested. The proper operation of the model verified the design. This model was used to develop the control and driver circuits.

The next phase was the construction of an engineering model which will be used for the RF cavity experiment in Los Alamos and will serve as a prototype for the future tuning magnet power supplies. The power supply is housed in two standard cabinets, one of them has the control and drive circuits, the other the high power bridge. The DC source is a separate unit.

CONCLUSION

The tuning magnet power supply utilizes unique circuit to supply the highly inductive load of the ferrite magnets with an accurate current wave. This circuit operates as an amplifier during the current rise and as a switching circuit during the current descent. The advantages of this solution are:

- inductive energy recovery
- accurate current control
- cost effective and reliable circuits
- use of commercially available components

REFERENCES

[1] B.M.Han, G.G Karady, Power Supply For Accelerator Tuning Magnet.Proceedings of Int. High Tech. Conference, Scottsdale, AZ 1988